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RESISTANCE OF POTATO TUBERS TO SCAB

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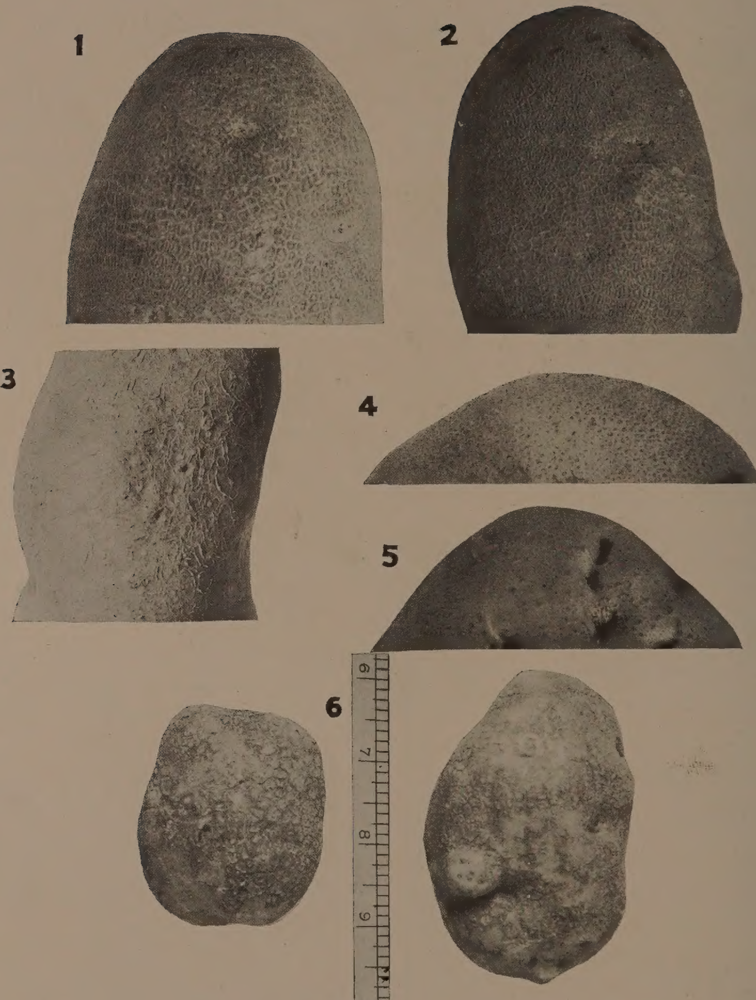

PLATE I.—Figure 1. Skin of Scab Proof. Figure 2. Skin of Cambridge Russet. Figure 3. Skin of Cowhorn. Figure 4. Skin of Rural New Yorker No. 2. Figure 5. Skin of Dibble's Russet. Figure 6. Peculiar russetting of Irish Cobbler.

BULLETIN 215: RESISTANCE OF POTATO TUBERS TO SCAB

By B. F. Lutman

Several investigators have made observations as to the amount of scab found on potato tubers. These records in most cases were incidental to tests of new varieties, yields, eating quality, etc., but they serve to indicate the amount of scab occurring under widely diverse environments and throughout a long series of years.

Beckwith (1) at Geneva, N. Y., tested 45 varieties during the dry growing season of 1887. He concluded that the tubers of dark-skinned varieties show less scab than those of the flesh-colored skin types and more scab than do tubers with relatively white skins, the figures being respectively 27, 53 and 43 percents.

Humphreys (11) in Massachusetts, in 1890, testing 14 varities, found Rural New Yorker No. 2 and White Seedling to be comparatively free from scab but was unable to detect any greater resistance in the thick skinned or red skinned sorts.

Kinney (13) in 1891, in Rhode Island, deemed some of the five varieties he tried more susceptible than others.

Rane and Hunt (17) in New Hampshire, noted the amount of scabbing on a number of varieties. Bliss' Triumph (32 percent scab) seemed more resistant than Green Mountain (72 percent scab).

Williams (20) in South Dakota, in 1894 and 1895, tested 21 varieties as to their scab resistance. Marked differences were noted, "the thicker skinned, dark colored varieties being less likely to suffer severely from scab than the paler colored, thin skinned ones."

Craig (4) at the Canadian Experimental Farms, in 1896, observed that Northern Spy was only slightly affected by scab while more than 90 percent of the Clarkes' No. 1 tubers were scabby.

Halsted (9) in New Jersey, in 1898, arranged the seven varieties he tested, beginning with the more resistant, as follows: (1) Rural New Yorker No. 2, (2) Rural Blush, (3) American Giant, (4) Queen, (5) June Eating, (6) Delaware, (7) Early Rose. He notes also that the deep scab is more common on the latter than on the other varieties. In 1899 he (10) similarly arranged seven varieties as follows: (1) State of Maine, (2) Queen, (3) White Star, (4) Early Rose, (5) Hebron, (6) Rural New Yorker No. 2, (7) Green Mountain.

Shepperd and Ten Eyck (18) in North Dakota, in 1902, tested 27 varieties. Four developed no scabby tubers, while there was from 64 to 78 percent scab on five varieties. All of the susceptible varieties

were red russets, while the color of the resistant ones in the main was white or rose. The eating qualities of the latter as a class were quite inferior.

Jones (12) in 1903, then located at the Vermont station, considered certain German (Richter's Imperator, Prof. Wohltmann, Irene), and American varieties (White Beauty, Carmen No. 3, American Giant, Sir Walter Raleigh, Irish Cobbler, Scab Proof, Aurora) to be somewhat scab resistant.

The most extensive observations on scab resistance were made by Stuart (19) at the Vermont station during 1906 and 1907, using 74 varieties. During both seasons the German variety Boncza—like Abou Ben Adhem—"led all the rest"; Million Dollar (American) ranked second in 1906 and sixth in 1907; Sir John Llewellyn (English) sixth and third; Ninety-fold (English) tenth and second; Fuerst Bismark (German) third and fourth.

Stuart states:

"1. That none of the varieties tested showed strongly marked scab resistant qualities when grown on soil well infested with scab organisms.

2. That the notion commonly prevalent to the effect that a russet skinned variety does not become scabby is not based on fact, as evidenced by the behavior of Cambridge Russet which occupied fourteenth position in 1906 and eighteenth in 1907. Personal observation during the past six years corroborates this statement.

3. That some varieties are apparently somewhat less subject to scab than are others (Boncza and others); but whether this immunity is wholly or only partially inherent cannot be determined from the data now in hand.

4. That there seems to be little hope of securing scab resistant varieties through selection."

The observations made thus far seem to agree on only a single point, namely, that some varieties of potatoes are more resistant than others. The current belief that red or dark skinned types resist scab better than the lighter colored ones does not seem to be sustained by the data then available. Doubt is cast also on the notion that the thicker skinned varieties are necessarily more resistant than those with thinner skins. In fact, these observations only permit us to recognize the resistance of some varieties without affording definite clue as to the underlying cause which induces resistance.

1914 Trials

The scab resistance experiments reported in this article were begun in 1914 at the Vermont station and continued for four years. The land was a very light sandy loam, known to be badly infected with the scab organism, more on the east portion than upon the west, a fact which should be kept in mind in drawing conclusions as to comparative results. All trials were often repeated in order, as nearly as possible, to equalize the conditions of the two sides of the plot. The land had been in hay during 1913 and it had received a somewhat heavy application of stable manure as a topdressing, which was repeated during the winter and spring as a precedent to the 1914 crop.

Most of the seed was obtained through the courtesy of Prof. Wm. Stuart of the Federal Department of Agriculture, formerly horticulturist of this Station, who furnished some 20 varieties, and of Prof. C. A. Zavitz of the Ontario Agricultural College. The American varieties were planted during late May and the Canadian ones on their arrival on June 18. In addition to these, Cowhorn, a peculiar dark purple, thick skinned sort that is grown to some extent in the mountain regions of Vermont, was planted. Each variety was set in a short row of about 25 plants, on both the east and the west portions of the plot. The seed was practically free from external indications of scab and, in a few cases, was disinfected with formaldehyde in order to insure the destruction of any possible sources of infection. Every tuber, both large and small, was individually examined and recorded, the many small tubers accounting for the apparently unusual numbers recorded as compared with the total weight.

The results appear in the following table:

TABLE I—SCAB RESISTANCE OF POTATO VARIETIES, 1914

(Arranged in order of freedom from scab)

Variety	Weight of tubers	Number of clean tubers	Number of slightly scabby tubers*	Number of badly scabby tubers	Clean tubers	Slightly scabby tubers	Badly scabbed tubers
	lbs.				%	%	%
Cambridge Russet	38	264	46	0	85.2	14.8	0
Scab Proof	31.7	238	54	0	81.5	18.5	0
Cowhorn	57.5	313	173	16	62.3	34.5	3.2
Burbank's Russet	53.7	285	213	1	57.1	42.7	0.2
Dakota Red	64.2	203	208	6	48.7	49.8	1.5
Million Dollar	45	131	195	8	39.2	58.4	2.4
White Ohio	71	203	295	45	37.4	54.3	8.3
Dibble's Russet	63.6	132	225	3	36.6	62.4	1
Rural New Yorker No. 2	67.8	119	324	4	26.6	72.5	0.9
Beauty of Hebron	93.7	286	487	48	25.8	67.6	6.6
Irish Cobbler	64.5	114	263	146	21.8	50.3	27.9
Early Rose	61.8	111	345	100	19.9	62.1	18
Twentieth Century	47.2	48	258	55	13.3	71.5	15.2
Pride of Vermont	50	41	262	60	11.3	72.2	16.5
Vermont Gold Coin	51.5	61	392	101	11	70.8	18.2
Moroton Beauty	8.7	12	102	8	9.9	83.6	6.5
Extra Early Eureka	18.5	12	111	13	8.8	81.6	9.6
Bovee	65.1	39	546	118	5.5	77.7	16.8
Early Ohio	51	12	314	16	3.5	91.8	4.7
Triumph	29.5	10	320	60	2.5	82.1	15.4
Norcross	69.3	18	309	254	3.1	53.2	43.7
White Star	67.4	16	293	309	2.6	47.4	50
Average					27.9	59.9	12.2

*Less than 5 percent of surface; not more than one or two large scabs on a fair sized tuber; not enough materially to injure the tuber for sale or seed.

It is clear that at the head of the resistant class stand the potatoes of the russet type. It should be noted that Scab Proof is one of the thickest skinned of these russets. Cowhorn and Dakota Red (a red skinned variety) yielded practically as high a percentage of clean tubers. The susceptible varieties are, in the main, white skinned, although Triumph is pink skinned. The thickness of the skin seemed to have more to do with the quality of resistance than the color.

A comparison of yields from scabby and clean tubers was made in certain trials conducted on the land immediately east of that on which the varieties were tested. The soil was as much inclined to produce scabbiness as any that could be found. Green Mountain tubers, both clean and scabby, were used. The clean seed were not disinfected but betrayed no trace of scab. The scabby seed were at

least half covered by disease. Alternate rows were planted, three scabby and three clean. The slightly scabby tubers were counted as in the preceding experiment. The results were as follows:

	Number of hills	Clean tubers	Slightly scabby tubers	Badly scabby tubers	Weight of large tubers	Weight of small tubers	Total weight of tubers	Weight per plant
					lbs.	lbs.	lbs.	lbs.
Clean	108	0	259	844	93.3	42.3	135.6	1.25
Scabby	121	0	376	928	104.1	51.2	155.3	1.28

No clean tubers were produced and there were as many badly scabbed in the one case as in the other. The difference in yields of slightly scabby tubers, however, is a little in favor of the scabby seed. This result is hardly to be expected for the reason that the planting of tubers as badly affected by the disease as were those used for seed, gave as much chance for infection as would the placing of a heavy inoculation or a spadeful of manure at the exact place in which the young tubers are to be formed.

The almost absolute identity of the individual plant yields from clean and from scabby seed is interesting in view of the claims to the contrary made by Goff (7) and Bolly (2) to the effect that extreme scabbiness of seed tends to lessen the crop. In this trial, at any rate, the scabby seed produced as largely as did the clean seed.

1915 TRIALS

The same land was used in 1915 and the same seed—with minor exceptions—was grown in the same soil. The large percentage of scab infection made disinfection necessary, hence all varieties were soaked for two hours in formaldehyde solution. The results follow:

TABLE II—SCAB RESISTANCE OF POTATO VARIETIES, 1915

Variety	Yield per hill	Number of clean tubers	Number of slightly scabby tubers	Number of badly scabby tubers	Clean tubers	Slightly scabby tubers	Badly scabbed tubers
	lbs.				%	%	%
Scab Proof	2.11	691	10	0	98	2	0
Cambridge Russet	1.85	575	18	0	97	3	0
Burbank's Russet	2.5	600	66	20	87.4	9.6	2
Cowhorn	3.01	131	403	193	18	55.4	26.6
White Ohio	1.6	91	304	91	18.7	63.6	18.7
Early Ohio	1.5	68	362	47	14.2	75.9	9.9
Early Rose	1.94	100	508	110	13.9	70.7	15.4
Beauty of Hebron	2.73	117	476	275	13.5	54.8	31.7
Triumph	1.03	51	311	57	12.2	74.2	13.6
Million Dollar	2.21	47	307	81	10.8	70.6	18.6
Dibble's Russet	2.51	42	367	101	8.2	72	19.8
Irish Cobbler	1.97	59	580	98	7.9	75.5	16.6
Dakota Red	2.72	47	358	233	7.3	56.2	36.5
Bovee	2.08	54	387	268	7.6	54.4	38.0
White Star	3.04	56	450	365	6.4	51.6	42.0
Rural New Yorker No. 2	2.82	28	443	127	4.7	74.0	21.3
Davies' Warrior	1.04	21	264	239	4.0	50.3	45.7
Vermont Gold Coin	2.01	32	311	382	4.4	42.8	52.8
Pride of Vermont	2.38	21	337	387	2.8	45.2	52.0
Green Mountain	3	11	538	255	1.3	66.9	31.8
Norcross	2.61	2	209	626	0.2	24.9	74.9
Average					20.9	52.1	27

The russet varieties, as in the preceding year, stand at the top of the list for disease resistance, whereas Cowhorn and Dakota Red seem to some extent to have lost their preeminence and to have dropped into the middle class.

1916 TRIALS

The same land was again used in 1916, commercial potato fertilizer being used in the furrows before planting. All seed was disinfected. Professor Stuart furnished several seedlings originated in the Federal Department for testing as to disease resistance. These are indicated by his numbers. Three English varieties, Ninety-fold, Sir John Llewellyn and Reading Russet were bought from Sutton & Sons of Reading, Eng., but arrived in such poor condition that only a few of them could be planted. The low yields from the first two may be explained by the fact that they were only planted once in the field and not repeated as were the other varieties.

TABLE III—SCAB RESISTANCE OF POTATO VARIETIES, 1916

Variety	Weight of tubers	Number of clean tubers	Number of slightly scabby tubers	Number of badly scabby tubers	Clean tubers	Slightly scabby tubers	Badly scabbed tubers
	lbs.				%	%	%
Scab Proof	16.0	36	42	21	36.3	42.4	21.3
Burbank's Russet	21.8	87	49	78	40.6	22.9	36.5
Cambridge Russet	14.5	56	79	23	35.5	50.0	14.5
1665	70.3	17	91	537	2.6	14.1	83.3
4227	72.8	46	164	745	4.8	17.2	78.0
3766	44.8	11	113	558	1.6	16.6	81.8
1212	67.2	64	95	883	6.1	9.1	84.8
15284	38.8	0	68	363	0	15.8	84.2
13660	70	0	92	494	0	15.7	84.3
17087	56	4	78	595	0.6	11.5	87.9
3760	59.8	6	82	544	1	12.9	86.1
Ninety-fold	6.5	1	14	67	1.2	17.1	81.7
Sir J. Llewellyn	14.5	5	27	192	2.2	12.0	85.8
17365	73.2	0	58	573	0	9.2	90.8
13222	55.3	3	32	350	0.8	8.3	90.9
7322	43	0	40	435	0	8.4	91.6
11844	30.8	3	18	227	1.3	7.2	91.5
3073	61.2	11	37	545	1.8	6.2	92.0
22245	32.5	0	31	329	0	8.6	91.4
21781	28.8	0	35	397	0	8.1	91.9
22725	30.7	0	31	331	0	8.6	91.4
22723	34.5	0	32	447	0	6.7	93.3
22597	26	0	15	225	0	6.3	93.7
2590	45.8	1	30	656	0.1	4.4	95.5
1147	32.3	5	18	416	1.1	4.1	94.8
4755	32.3	7	13	385	1.7	3.2	95.1
5727	57.5	0	36	676	0	5.1	94.9
7192	30.5	0	12	276	0	4.2	95.8
14329	73.8	0	45	885	0	4.9	95.1
Davies' Warrior	17.5	0	12	172	0	6.6	93.4
Cowhorn	23.5	5	9	169	2.9	4.9	92.2
Rural New Yorker No. 2	17.3	0	8	128	0	5.9	94.1
Dibble's Russett	23	0	8	162	0	4.7	95.3
7735	29	0	9	295	0	3	97
4240	56.3	0	17	558	0	3	97
225	41.8	0	8	547	0	1.4	98.6
23083	21.8	0	4	298	0	1.3	98.7
White Star	11.5	0	3	142	0	2	98
Beauty of Hebron	14.3	0	6	178	0	3.2	96.8
Vermont Gold Coin	15.2	0	2	158	0	1.25	98.75
Million Dollar	30.5	0	5	219	0	2.2	97.8
Bovee	27.8	0	1	233	0	0.43	99.7
Early Rose	12.0	1	4	167	0.6	2.3	97.1
Norcross	20.5	0	1	179	0	0.6	99.4
Reading Russet	30	0	5	222	0	2.2	97.8
Green Mountain	30.8	0	2	240	0	0.8	99.2
Irish Cobbler	17.3	0	0	199	0	0	100
Pride of Vermont	4.5	0	0	45	0	0	100
Dakota Red	30.5	0	0	260	0	0	100
Early Ohio	13.3	0	0	175	0	0	100
Triumph	16	0	0	213	0	0	100
White Ohio	13.5	0	0	145	0	0	100
Average of varieties (19) used in 1914 and 1915					5.3	6.9	87.9

The conspicuous feature of the results from the 1916 harvest is the enormous increase in the amount of scabbiness. While 27.9 percent of the tubers were clean in 1914 and 20.5 percent in 1915, only 5.3 percent were free from scab in 1916, confining the comparison to those varieties grown each year. On the other hand, the number of badly scabbed tubers had increased from 12.2 percent in 1914 to 28 percent in 1915 and to 87.9 percent in 1916. It will be noticed that nearly half the large number of varieties grown were affected by scab to an extent in excess of 95 percent. It should be noted in this connection that no manure whatever had been applied to the land since 1914, commercial fertilizer alone being employed, yet the parasitic strains of Actinomyces increased in this soil, notwithstanding the comparative lack of humus. Clearly these soil organisms do not readily succumb. Several investigators have noted similar increases in scabbiness on soils repeatedly planted to potatoes. Clinton says: "The first year the potatoes were on the land the percent of scab was so small that it was not determined. It certainly was below five percent and probably not over one percent. The second year, 1907, scabby tubers had increased to 22 percent, in 1908 to 47 percent (the same potatoes on our general rotation field this year gave only about one percent scabby), and in 1909 to 63 percent. The last two years the scab was so bad as to seriously affect the market value of the potatoes."

Tests were made of the so-called soil acidity of the experimental plot, samples being taken in various parts. It was estimated that its lime requirement was equivalent to 2,500 pounds calcium oxid per acre. The general notion that an alkaline soil reaction necessarily induces scab attacks was not upheld in the present instances.

Scab infestation had become so excessive on this plot that there seemed little likelihood that comparable results could be secured in the future and the trials were transferred in 1917 to a new location.

1917 TRIALS

The seed were planted in 1917 on land that had been in grass for eight years, on which during many years previous an orchard had existed. The stumps of some of the old apple trees were still in sight. Nothing was known as to its past history in relation to scab. Each variety was planted in two different locations in the field in order somewhat to compensate for variations in scab infestation. The fate of the crop was a hard one. The land had not been properly plowed and no

commercial fertilizer was used. The plants succumbed early in the season to tip burn, which was undoubtedly aggravated by a lack of available potash and, to make a bad matter worse, mosaic developed on at least half the varieties. The yields of some varieties was practically nil. The results appear in the following table, stated in the order in which the varieties were planted in the field.

TABLE IV—SCAB RESISTANCE OF POTATO VARIETIES, 1917

Row	Variety	Total number of tubers examined	Clean tubers	Slightly scabby tubers	Badly scabbed tubers
			%	%	%
1	Cambridge Russet	237	36.2	62.8	1
2	Dibble's Russet	480	21	72.5	6.5
3	Dibble's Russet (disinfected)	278	24.8	70.8	4.4
4	4240 (disinfected)	611	21.2	75.6	3.2
5	Early Rose (disinfected)	415	21.7	72.5	5.8
6	Early Rose	322	13.3	78.2	8.5
7	22083 (disinfected)	250	0.8	90	9.2
8	Green Mountain (disinfected)	286	14.3	78.6	7.1
9	Green Mountain	299	6.8	77.2	16
10	Cowhorn	30	60	40	0
11	Burbank's Russet	66	57.5	41	1.5
12	Ninety-fold (disinfected)	122	0.7	87	12.3
13	Reading Russet (disinfected)	210	1	89.5	9.5
14	5727	513	4.7	84.2	11.1
15	5727 (disinfected)	665	8.8	81.9	9.3
16	Bovee (disinfected)	513	7.4	86.5	6.1
17	Bovee	577	4.3	79.7	16
18	1665 (disinfected)	470	3.6	93.8	2.6
19	4227	481	4.5	91.5	4
20	4227 culls (disinfected)	369	3	88.6	8.4
21	3073 (disinfected)	477	1.2	94.1	4.7
22	Sir John Llewellyn (disinfected)	418	19.6	80.4	0
23	3766 (disinfected)	400	0.8	91	8.2
24	Bovee (disinfected)	578	25.7	74	0.3
25	Bovee	535	11	80.7	8.3
26	Scab Proof	327	62.1	37.9	0
27	Green Mountain (disinfected)	344	1.1	92.4	6.5
28	Green Mountain	417	7	84.9	8.1
29	Green Mountain (disinfected)	393	10.1	81.1	8.8
30	Green Mountain	278	5	85.3	9.7
31	Scab Proof	191	39.8	56.5	3.7

A detailed study of certain bacteria contaminating foods.

TABLE V—POTATO VARIETIES, 1917, ARRANGED IN THE ORDER OF THEIR RESISTANCE TO SCAB

Variety	Clean tubers	Slightly scabby tubers	Badly scabbed tubers
	%	%	%
Cowhorn	60	40	0
Burbank's Russet	57.5	41	1.5
Scab Proof	55.9	47.2	1.8
Cambridge Russet	36.2	62.8	1
Dibble's Russet	22.9	71.6	5.4
4240	21.2	75.6	3.2
Sir John Llewellyn	19.6	80.4	0
Early Rose	17.5	75.3	7.1
Bovee	12.1	80.2	7.6
Green Mountain	7.4	83.2	9.2
5727	6.7	83	10.2
4227	3.7	90	6.2
3073	1.2	94.1	4.7
Reading Russet	1	89.5	9.5
22083	0.8	90	9.2
3766	0.8	91	8.2
Ninety-fold	0.7	87	12.3

The results of disinfection with formaldehyde may be summarized as follows:

TABLE VI—EFFECT OF DISINFECTION ON AMOUNT OF SCAB, 1917

Varieties	Clean tuber *not* disinfected	Disinfected	Slightly scabbed tubers *not* disinfected	Disinfected	Badly scabbed tubers *not* disinfected	Disinfected
	%	%	%	%	%	%
Dibble's Russet	21	24.8	72.5	70.8	6.5	4.4
Early Rose	13.3	21.7	78.2	72.5	8.5	5.8
Green Mountain	6.8	14.3	77.2	78.6	16	7.1
5727	4.7	8.8	84.2	81.9	11.1	9.3
Bovee	4.3	7.4	79.2	86.5	16	6.1
4227	4.5	3	91.5	88.6	4.0	8.4
Bovee	11	25.7	80.7	74	8.3	0.3
Green Mountain	7	1.1	84.9	92.4	8.1	6.5
Green Mountain	5	10.1	85.3	81.1	9.7	8.8
Average of above six varieties	8.6	13	81.5	80.6	9.8	6.4

In nearly all cases where the seed was treated a slight increase occurred in the percentage of clean tubers and a slight diminution in that of badly scabbed tubers.

The 1917 results confirm those of the preceding years. The russet types stand at the head of the list for scab resistance but have asso-

ciated with them the variety Cowhorn. Dibble's Russet, 4240 and Sir John Llewellyn occupy a middle position on the scale of resistance, while the other varieties follow with varying percentages. The small percentage badly scabbed as compared with 1916 shows that the transfer to new land had brought a marked improvement and that the heavy percentage of scabbing in 1916 was due to the land and not to the season. Seasonal data on scabbing must be accepted with caution for the reason that it is common to change the location of the planting yearly in order to lessen scab ravages, a practice which makes it difficult to institute accurate comparisons.

General Conclusions.

1. Repeated planting of potatoes on the same soil increases the percentage of scab even if no manure or lime is added to the soil.

2. Marked resistance to scab is found in the true russet types of tubers. The semi-russets show some scab resistance while the white, thin skinned varieties seem to be most susceptible.

The Relation of the Thickness of the Skin of Potato Tubers to their Resistance to Scab

The results of the field trials at the Vermont station have led to the conclusions that the thickness of the skin of the tubers has much to do with their resistance to scab. The russet skinned types, with their very thick, corky skin layers, seemed to stand in a class by themselves in respect to their ability to withstand the inroads of disease.

Small pieces of tuber skins representing several varieties were fixed in Flemming's weaker mixture, imbedded in paraffin, cut and stained. It was then (1915) thought that the determination of the number of cell layers was all that would be necessary and no attention was given to the actual thickness of the samples. Furthermore, an unforeseen difficulty was encountered in that the skin of a single tuber varied profoundly in one spot as compared with another. Few American varieties exhibit entirely smooth surfaces, a careful examination revealing scales where the cork layers are very thick and, often, thinner portions where the protective layers seem to be much fewer in number. It is easy to see that the difficulties of representative sample taking under the circumstances are extremely great and that much opportunity is offered for personal bias in the matter of selection. The writer was unable to devise any method that would eliminate this

personal equation but he attempted to be as fair as possible in sample taking. Potato tubers with diameters lying between one and six centimeters were used for the section in these earlier trials. Scab infections, especially the deeper ones, must occur when the tuber is only partly grown and the protective layer that covers it at that time must be the one which will prevent—if it prevents at all—the entrance of the parasite. At least 30 counts were made from five or more slides in each instance.

The writer wishes to acknowledge the help of Mr. H. E. Bartram, formerly assistant plant pathologist, in the work of making the sections and counts on the varieties and on a part of those made after different soil treatments.

TABLE VII—NUMBER OF CORK LAYERS ON GROWING TUBERS

		Cell layers
Dibble's Russet,	tubers about 2 cm. diameter........	8.9
White Star,	" " 2 " "	8.7
Burbank's Russet,	" " 3 " "	11.5
Rural New Yorker No. 2,	" " 6 " "	8.7
Irish Cobbler,	" " 6 " "	8.8
Scab Proof,	" " 7 " "	8.7
Scab Proof,	" " 3 " "	12.3
Dakota Red,	" " 1 " "	7
Dakota Red,	" " 2 " "	8.5
Triumph,	" " 3 " "	8.9
Early Ohio,	" " ½ " "	7.8
Cambridge Russet,	" " 1 " "	7.6
Cambridge Russet,	" " 1 " "	7.6
Cambridge Russet,	" " 2 " "	8.5
Green Mountain,	" " 2½ " "	6.7
Beauty of Hebron,	" " 3 " "	7.1
Cowhorn,	" " 2 " "	7.9
Bovee,	" " 2 " "	8.1

It is doubtful whether these determinations mean very much; yet the fact cannot be gainsaid that very susceptible varieties, such as Green Mountain, Early Ohio, Beauty of Hebron and Bovee, are among the very thin skinned varieties, whereas Burbanks' Russet and Scab Proof possess much thicker cork layers. The majority of the varieties tried, however, lie midway between the two extremes as they do in their resistance to scab in the field. Exceptions to this are to be noted in Cowhorn and Cambridge Russet, both fairly resistant varieties, which do not seem to possess an unusual number of cork layers. It is entirely possible that the number of layers of cork in these two instances continue to increase as the tubers grow older, while in the other varieties the maximum is attained earlier. It will be noticed in this con-

nection that the cork layers on Scab Proof increase in thickness from 8.7 layers when the tubers are one centimeter in diameter to 12.3 layers when they are six centimeters in diameters; and it should be noted in that connection that the russet appearance develops while the tubers are thus growing, a fact which may well account for the additional layers.

Further data were desired as to more mature tubers; hence a series of sections was cut from potatoes grown in 1917 on another plot. The potato pieces were cut on a freezing microtome, as will be described in detail later. No attempt was made to secure average samples. The measurements were made of thick and thin spots, if such were present, and the records kept separately. No attempt was made by calculation to arrive at the probable average thickness of the skin for the tuber as a whole.

TABLE VIII—THICKNESS OF CORK LAYERS ON MATURE TUBERS

Variety	Thick portion cell layers	Thin portion cell layers	Thick portion microns	Thin portion microns
Early Rose	14	9.7	120	95.9
Reading Russet	....	12.5	....	111.5
Bovee	none	7.8	none	97
Sir John Llewellyn	....	8.4	....	96.3
Burbank's Russet	12.7	7	182.2	87.5
Irish Cobbler	9.8	7.6	116.6	86.6
Cowhorn	....	12.6	....	138.6
Dibble's Russet	10.9	6.7	137	100
Green Mountain	9.5	6.6	110	89.2

The measurements taken from the sections corroborate the external appearance of the tubers. Green Mountain, Early Rose and Irish Cobbler exhibit scales or scurf, but these scales are not nearly as pronounced on Dibble's Russet and the measurements of the thick portions (in microns) show that they are not as thick. Reading Russet seemed to have no thin places in its cork layers, the skin being uniform and fairly thick. The same may be said of Cowhorn. Burbank's Russet does not exhibit an unusual number of cork layers in its thin portions, but the russetted areas have a high number of cells which form a thick layer.

The thick and thin portions alternate with considerable regularity in sections of Scab Proof, so it was possible to measure their width on a series of sections. A series of the russetted portions measured in width 1520 square microns in cross section and the width of the thinner parts between them was 6456 square microns. The area covered by

the two types of surface of the skin of the tuber would be represented by the square of the above figures, *i. e.*, by the proportion of 2,310,400 to 41,679,936. This is equivalent to saying that over twenty times as much of the entire skin area is covered by the russetted areas as is covered by the thinner portions.

Surface views of the skins of a number of varieties of tubers are shown on plates I and II. Figures 1-2, inclusive, are natural size while figures 7-14, inclusive are magnified about six diameters. The latter figures were taken with a Micro-Tessar lens and long bellows camera.

The net-like appearance of the skin of the russet types is shown by figure 1 of Scab Proof and figure 2 of Cambridge Russet. The above calculation as to the extent of the russetted area is substantiated by the magnified view of the outside of the tuber. The thinner scales, such as occur on most American varieties, are seen in figure 3 of Cowhorn, figure 4 of Rural New Yorker No. 2 and figure 5 of Dibble's Russet. These scales are large on the skin of Cowhorn, while on most varieties they are much smaller. Cracks often develop in the outer corky layer on Cowhorn.

The russetting on the Irish Cobbler potatoes in figure 6 is believed to be due to the stimulus of fertilizers. It is the common belief among growers that heavy applications of commercial fertilizer have a tendency to russet the tubers. The tubers shown exhibited the russetting on the side on which there was a thick deposit of sulphur.

The thick russet layer on Scab Proof and Burbank's Russet is even more clearly shown in figures 11 and 13 in which the surface is magnified about six diameters. The lenticels on these varieties can be seen as white spots above the x on either figure. The ease with which the lenticels can be seen on the skin of these varieties has been exaggerated since they are usually so deeply imbedded in the thick cork layers that it is difficult to distinguish them from a scale. In fact it is almost impossible to see them on a dry potato and hence these tubers were kept moist for an hour or two before the photograph was taken in order to swell the lenticels so that they would show.

The skin of Cowhorn (figure 7) when magnified looks very much like morocco leather. The clefts in the thick corky layers are comparatively small in area as compared to the thicker portions. The granular structure seems to be due to the large pigmented cells which lie under the corky layer and give to the tuber its dark purple color.

Green Mountain (figure 8) and Dakota Red (figure 9) have

PLATE II.—Figure 7. Skin of Cowhorn × 6. Figure 8. Skin of Green Mountain × 6. Figure 9. Skin of Dakota Red × 6. Figure 10. Skin of Bovee × 6. Figure 11. Skin of Scab Proof × 6. Figure 12. Skin of Rural New Yorker No. 2 × 6. Figure 13. Skin of Burbank's Russet × 6. Figure 14. Skin of Early Rose × 6.

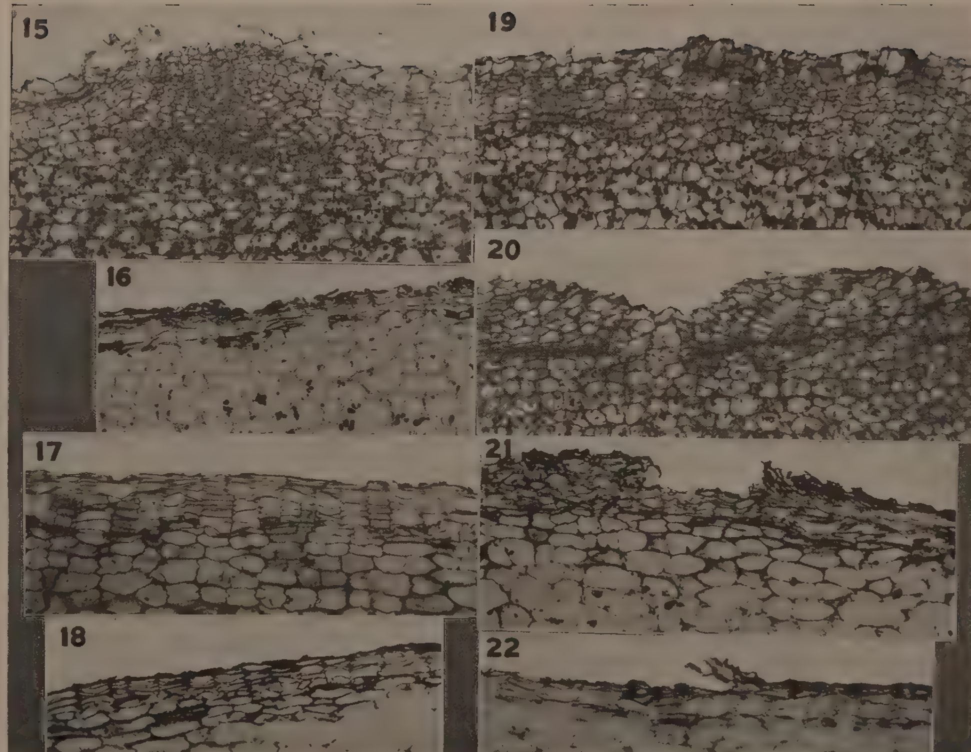

PLATE III.—Figure 15. Cross section of lenticel, Dibble's Russet × 90. Figure 16. Cross section of skin of Dakota Red × 90. Figure 17. Cross section of skin of Cowhorn × 90. Figure 18. Cross section of skin of Irish Cobbler × 90. Figure 19. Cross section of skin of Scab Proof, before surface markings appear × 90. Figure 20. Cross sction of skin of Scab Proof, after surface markings appear × 90. Figure 21. Cross section of skin of Scab Proof, old tuber from storage × 90. Figure 22. Cross section of skin of Dibble's Russet × 90.

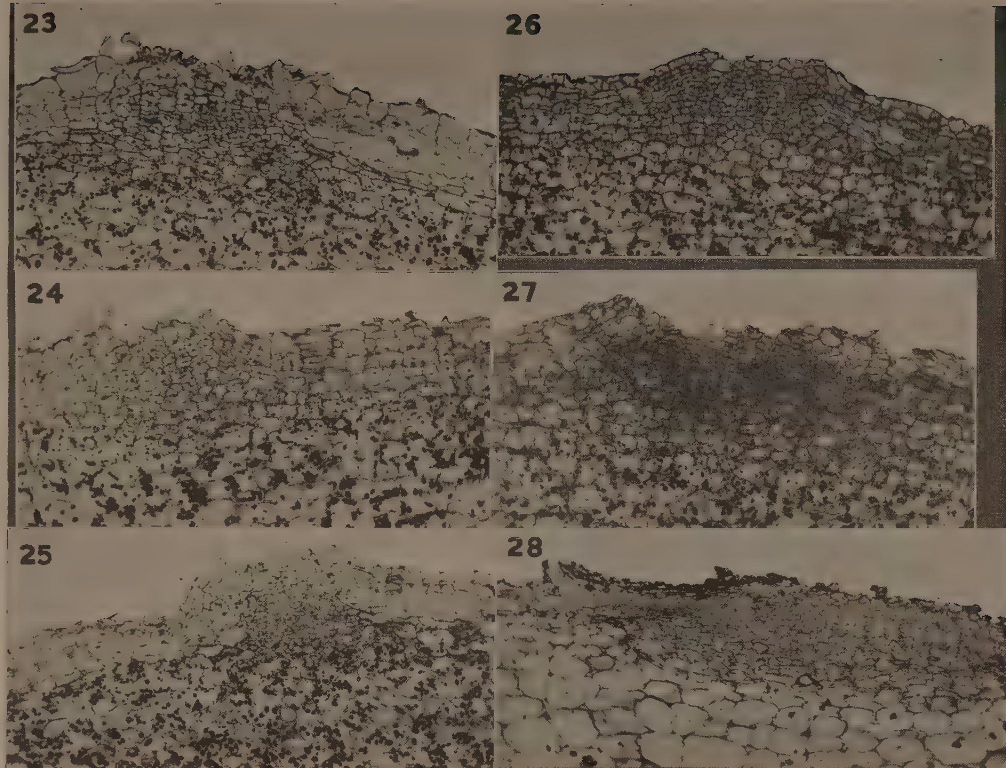

PLATE IV.—Figure 23. Cross section of lenticel of Green Mountain × 90. Figure 24. Cross section of lenticels of Dakota Red × 90. Figure 25. Cross section of lenticel of Bovee × 90. Figure 26. Cross section of lenticel of Scab Proof from a small tuber × 90. Figure 27. Cross sction of lenticel from an old mature tuber × 90. Figure 28. Cross section of a lenticel of Burbank's Russet × 90.

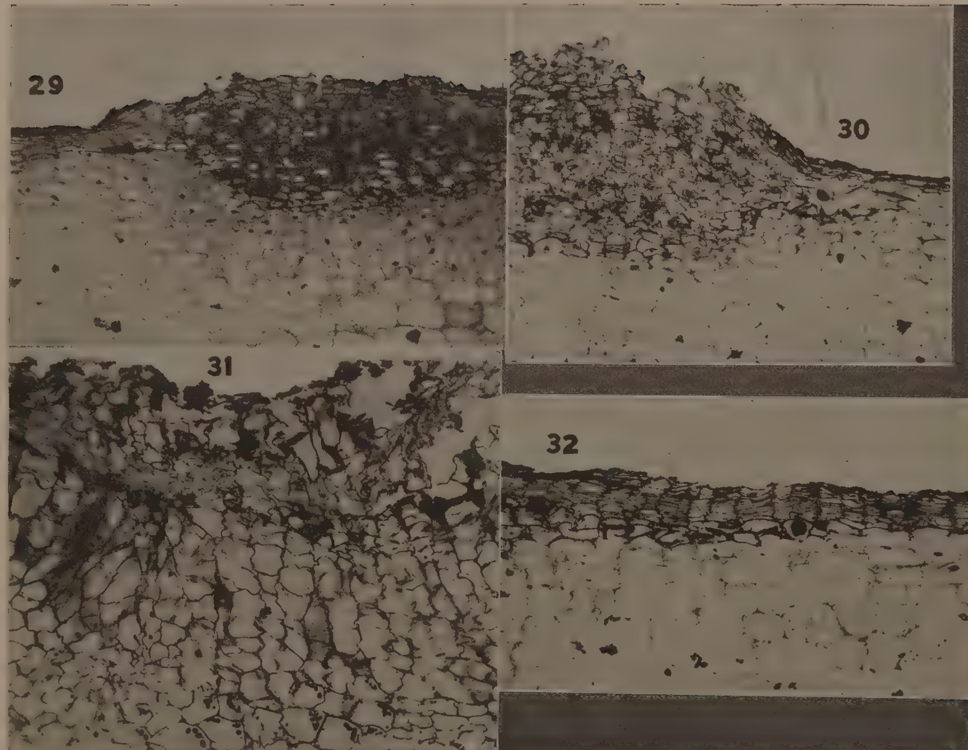

PLATE V.—Figure 29. Cross section of lenticel from Dibble's Russet showing early scab lesion × 90. Figure 30. Cross section of lenticel of Bovee showing early scab × 90. Figure 31. Cross section of scab lesion on Irish Cobbler showing the effect of the scab organism on the storage tissue × 90. Figure 32. Cross section of scab lesion on Early Ohio × 90; hypertrophied cells with suberized walls showing under the cork layers; no evidence of the proximity of a lenticel through which infection may have occurred.

comparatively smooth surfaces but clefts occur in them, which in some cases cause them to assume somewhat of a russet appearance. Bovee (figure 10) and Early Rose (figure 14) both grow smooth surfaced tubers but even in these varieties both thicker and thinner skin regions seem to occur. The large size and prominence above the surface of the lenticels of these two tubers is very marked. They protrude above the surface and invite infection, while on the russet types the lenticels lie imbedded in a mass of corky tissue.

The sections confirm the surface indications and disclose certain facts as to structure of the skin textures that are of interest. Dakota Red (figure 16), Cowhorn (figure 17), Irish Cobbler (figure 18) and Dibble's Russet (figure 22) are comparatively smooth varieties and the sections show no marked differences in one as compared with the other. Cowhorn has a few more layers of cork and Dibble's Russet shows a section of one of the thin scales which cover the tuber. The cork cells of Cowhorn, however, exhibit one peculiarity, which, while it shows in the reproduction, is still more clearly observed in the sections. The cork cells of most varieties become crushed down against the tuber proper and their walls are crumpled and irregular. In Cowhorn, however, the walls of these cells seem to be of a firmer nature and the cells retain their rectangular shape in section. They are easily counted in sections, whereas it is almost impossible to distinguish the number of layers in tubers like those represented by figure 22, where the cell walls lie crushed one against the other.

The development of the russet areas on potatoes of this type is shown in figures 19-21. The very small tubers are, of course, smooth and not yet russetted. Figure 19 was taken from sections of such very young tubers. The cork layer at this time is thick and the cells are full and plump, but no thick or thin places have as yet developed. The material from which figure 20 was taken was fixed immediately after the tuber was taken from the soil and the cells stand out with turgid walls. The number of cells in the cork cambium region is sometimes difficult to count accurately. An old tuber taken from the storage bin was used for the section for figure 21 and the cork cells have been so crushed that it is almost impossible to count them.

Thickness of skin, while it is probably important, may not be the only factor involved in resistance or susceptibility to scab. As the writer has shown in a previous paper (16) and as had been still earlier pointed out by Frank (6), lenticels are the usual place of en-

trance for the scab organism. Probably all very deep scabs originate from the lenticels; hence their structure and position in the several varieties assume an importance certainly as great as if not greater than the structure of the skin itself. Sections of lenticels on growing tubers with a diameter of 1-6 centimeters are shown in figure 15 of Dibble's Russet, figure 23 of Green Mountain, figure 24 of Dakota Red, figure 25 of Bovee, all of which are susceptible to or only moderately resistant to scab. The protrusions of these structures above the level of the tuber is pronounced in several of these figures. The other character which is more easily made out in the sections than in these figures is the somewhat loose construction of the lenticels itself. The cells are rather large and do not seem to differ much from those of the cork cambium. The nuclei are large and the cells give every indication of being active and capable of continued division. The introduction of the scab organism here may easily divert them to the abnormal, cork formation of the type described by the writer as typical of scab tissue.

In contrast to the structure of the lenticels of these more susceptible varities should be set forth the lenticels of Scab Proof and Burbank's Russet, both of which are very susceptible. That of the very young Scab Proof (figure 26) would seem to be hardly distinguishable from the lenticels of susceptible types. Its cells are possibly a little rounded in section and not as rectangular. An old lenticel from a tuber well russetted is likely to lie below the level of the surface due to the continued growth of the cork to form the thick portions of the skin. The large lenticel in Burbank's Russet (figure 28) is partly covered by the thick russet scale at its left margin. The depth to which the lenticel tissue extends into the tuber should be noted as well as the very small size of the cells, their roundness, and the generally close structure of the tissue. Penetration by hyphae would seem to be more difficult than in the lenticels exhibited in figures 15, 23, 24 and 25.

The early stages of infection with the scab Actinomyces has been discussed at some length by the writer in another paper (16) but figures 29-32, inclusive, bring out some points that are of interest. Figure 29 shows the lenticel filled with cork cells with abnormally thick walls which stain very densely. The cork cambium layer at the bottom of the scab is not distinct. Part of the cells in the other lenticel (figure 30) from Bovee are fairly normal, while others are hypertrophied and exhibit very thick walls. The cork cambium layer is

still fairly distinct at the base of the lenticel tissue. Figure 30 (Irish Cobbler) is of interest because the storage tissue has become involved in the scab. The writer (16) has claimed that scab tissue is largely of the cork or cork-like type and derived from the outward growth of cells from the cork cambium. In this section, however, which is apparently of a shallow scab and possibly not from a lenticel, the growing layer seems to be throwing off abnormal cork cells peripherally and also internally giving rise to large, hypertrophied, empty parenchyma cells.

The formation of abnormal cells of the scab type beneath the cork layers is shown in figure 32. The stimulus of the Actinomyces may not have induced this condition in these cells but as scab was fairly common on all these tubers it is only fair to assume that it did. The corky covering of the potato is probably not without breaks through which the hyphal threads might grow and it is possible too that the excretion products of the organisms might be absorbed through the corky layer if the superficial growth was abundant.

EFFECT OF CHEMICALS ON AMOUNT OF SCAB

The ends of the varietal rows were utilized for tests of the effect of the application of sundry chemicals upon the amount of scab. The chemicals were scattered by hand in the furrows and then covered with soil. It was impossible to judge accurately as to the amount used, but apparently from 300 to 500 pounds per acre were employed. Germination was uninjured so far as observed. Clean Green Mountain tubers were used. Each of the various chemicals were tried at six different places on the plot and the results ought to be fairly indicative of the facts.

TABLE IX—EFFECT OF CHEMICALS ON SCAB

Treatment	Number of plants	Number of clean tubers	Number of slightly scabby tubers	Number of badly scabby tubers	Total number of tubers	Clean tubers	Slightly scabby tubers	Badly scabbed tubers
						%	%	%
Lime	51	63	269	112	474	14.2	60.5	25.3
Potassium carbonate	50	60	263	71	394	15.2	66.7	18.1
Ammonium sulphate	58	139	226	5	374	37.5	60.1	1.4
Potassium sulphate	42	112	221	51	384	29.2	57.5	13.3
Sulphur	52	97	310	32	439	22.1	70.6	7.3

The advantage gained by the use of ammonium sulphate and of sulphur as compared with lime or potassium carbonate is apparent at a glance. Practically all the tubers grown where ammonium sulphate was applied were marketable, although a majority of them were slightly scabbed. The tubers from the sulphur-treated rows were not of quite as high grade. The potassium sulphate rows might be regarded as controls, for it is doubtful if this salt produced any effect whatsoever. The two alkaline applications, lime and potassium carbonate, seemed to aggravate the trouble. An average percent of scab on ten varieties, exclusive of five somewhat resistant varieties grown on land immediately adjacent, was: 18.2% of clean, 66.8% of slightly scabby, and 15.0% of badly scabbed tubers. These figures serve as a check on the above treatments.

EFFECTS OF FERTILIZERS AND CHEMICALS ON THE THICKNESS OF SKIN

The studies made for a number of years at this Station, both in the field and laboratory, have conclusively shown that the thickness of the corky layers of the potato tuber had a decided influence on its resistance to the potato scab organism. Furthermore, it has been noted that the application to the soil of certain chemicals, such as sulphur and ammonium sulphate, enables even very susceptible varieties to some extent to withstand the ravages of the scab organism. The question naturally arises, therefore, whether there is possible connection between these two apparently related observations.

It must be noted, of course, that there are at least two possible effects that the addition of a chemical or fertilizer may have on the soil; it may affect either the parasite itself or its host plant. Under the conditions usually present in soil sulphur becomes oxidized and the ammonium sulphate molecule is cleaved in the soil, sulphur compounds, probably weak acids, being produced. It is assumed in the latter instance that the ammonia is oxidized to nitric acid while the free or uncombined sulphuric acid unites with the calcium of the calcium carbonate of the soil forming sulphate of lime and freeing carbon dioxid. The abnormal amount of acid thus formed undoubtedly serves to retard the growth of the scab Actinomyces. Furthermore it seems quite probable that the ions released when sulphur or ammonium sulphate are used exhibit an inhibitory toxic effect on their increase, an effect entirely distinct from and, it may be said, supplementary to induced acidity. Then again it is quite possible that such chemicals as sulphur

and ammonium sulphate applied to a soil may tend to stimulate the cork cambium to produce an unusually large number of cell layers, thus resulting in a very thick skin. On the other hand, such substances as lime or fresh manure may tend to inhibit such cambial divisions and, as a consequence, the skin of the tubers grown in areas thus treated may be found to be even thinner than is the case when tubers are grown on an ordinary unfertilized soil.

Kreitz (14) has done some interesting work touching the relation of the thickness of the tuber skin to soil, moisture and fertilizers. It is the latter factor that is of particular interest in the present study. Kreitz grew Dabersche potatoes on a piece of land which had received its last application of stable manure two years previous to the use for experimental purposes. His results are summarized in the following table:

TABLE X—EFFECT OF FERTILIZERS ON THE THINNESS OF SKIN LAYERS

	Thickness of skin microns	Number of cell layers
Kainit, 150 pounds per acre	208	8.3
Lime, 3,750 pounds per acre	240	8.3
Sodium nitrate, 50 pounds per acre	272	9.7
Salt, 270 pounds per acre	272	10.7
Acid phosphate, 150 pounds per acre	320	13.3
Control	288	11.3

In spite of these differences in thicknesses, the skin of the tubers, to all external appearances, seemed to be alike in all cases. It will be noticed that following the application of lime the skin was much thinner, while following that of the acid phosphate the reverse was the fact. Practical growers in this country often claim that the addition of too much fertilizer results in a russetting and irregular thickening of the skin of the tubers, but no one has observed that the liming of land makes potatoes thinner skinned. Sorauer, quoted by Kreitz (14), made the observation in 1871 that the skin of tubers on freshly manured land was thinner than that on land where the manure had been applied some time previously. He also found that varieties with red skins were less susceptible to the rot caused by *Phytophothora infestans* than the white skinned ones and connected up this fact with the thicker skins of the red types. Other authors, quoted in this same paper by Kreitz, are of the opinion that the smooth skinned varieties are less susceptable to the attacks of *P. infestans* because they furnish no lodging place for the spores.

The methods used in the present study of potato skins was essentially the same as those recommended by Lee (15) for sectioning animal tissues on a freezing microtome. In order to carry this through successfully preliminary treatment was found to be necessary. Small pieces of potato about $1 \times \frac{1}{2} \times \frac{1}{2}$ c. c. were dropped for 24 hours in a soaking solution, composed of equal parts of: 4 ounces of gum arabic dissolved in 6 ounces of water; 1 pound of loaf sugar boiled into solution in 1 pint of boiling water. Before freezing, the gum arabic-sugar solution was wiped from the block and it was frozen in the gum mucilage solution alone. The knife was kept covered with water and, as rapidly as the sections were cut, they were transferred to a dish of water. The gum and sugar soaked out of them and they resumed their normal size and shape.

The processes where the cork layers were stained in order to secure a differential stain was essentially the same as those recommended by Kreitz and ascribed by him to Tison. They were now placed for at least a few hours in a very weak alkaline solution of gentian violet, so highly diluted as to be quite transparent. The sections were then removed from this solution and washed in an eight percent solution of hydrochloric acid. The color was removed by this treatment from all of the walls except those impregnated by suberin. A short wash in tap water was necessary to restore this color at times to these portions. The sections were then spread on slides in 10 percent glycerin which was exposed to the air for 24 hours without a cover glass. At the end of this time the fluid had become quite concentrated and a little 50 percent glycerin was added, the sections were covered and examined. The stain gradually soaked out of the cork layer, but it was not necessary to examine the sections for some time.

The first series studied in this way were grown in the summer of 1916 on land on which potatoes had been planted the previous year. The tubers were stored in paper bags in the greenhouse basement and examined from time to time during the winter. The fact that the examination extended over five or six months made the author very doubtful as to the accuracy of the results, since in the intervening time an opportunity might have been afforded for the cork layers to increase in thickness. The first series were made from these potatoes, however, and the results are presented in the following tables, about which a few explanations seem necessary.

Kreitz gives no indication as to the allowance which he made for differences in the thickness of the skin in russetted as compared with

clear portions. The majority of the potatoes studied here showed some portions of the skin very much thicker than others. It was something of a problem to decide just what disposal to make of them.

It was finally decided to separate entirely the two sorts of measurements and then to try, in some cases, to combine them in about the proportion in which they seemed to occur in the sections. The data derived from the examination the thin portion seemed likely to be more nearly comparable to that used by Kreitz. An average of about 50 measurements were taken but it was found to be very difficult to avoid picking places that were thick or thin, that is to say it was almost impossible to eliminate the personal equation. An examination of the results will show that they are not at all consistent on the various sorts tested. The cell layers on the russetted portions, moreover, are often very confused and broken, so that it is probable that the thickness in the thinner portions more nearly represents the correct thickness.

The growing reason of 1916 was an abnormal one which may further explain the decidedly divergent results secured. The potatoes were grown on very light sandy soil and the tubers were almost baked during the extreme weather of early August.

Chemicals were applied as follows: Salt, 700 pounds; sodium nitrate, 128 pounds; slaked lime, 8,300 pounds; fresh manure, liberal dressing; sulphur, 435 pounds; acid phosphate, 390 pounds; commercial fertilizer, 2,000 pounds; coal ashes, 9,500 pounds; ammonium sulphate, 300 pounds. The potato fertilizer used contained 3.3% nitrogen, 13% total phosphoric acid, 8.8% available phosphoric acid and 8.8% potash. The nitrogen was derived in part from nitrate of soda and in part from tankage.

TABLE XI—EFFECT OF CHEMICALS ON THICKNESS OF THE SKINS OF POTATO TUBERS

Variety	Chemical or fertilizer used	Cell layers in thick portion	Cell layers in thin portion	Thickness, thick portion	Thickness, thin portion	Maximum thickness		Minimum thickness	
				microns	microns				
Dibble's Russet	Salt	10.3	6.8	164.3	102.1	14 207.2	cells microns	5 74	cells microns
	Sodium nitrate	9.6	6.6	168.7	112.5	12 207.2	cells microns	5 74	cells microns
	Slaked lime	10.3	6.9	180.6	119.9	14 266.4	cells microns	5 88.8	cells microns
	Fresh manure	10.4	6.5	179.1	117	12 207.2	cells microns	5 74	cells microns
	Sulphur	11.8	7.5	202.8	125.8	18 266.4	cells microns	5 88.8	cells microns
	Acid phosphate	10.2	7.4	186.4	122.8	12 236.8	cells microns	5 88.8	cells microns
	Complete fertilizer	14.6	7.4	222	130.2	18 281.2	cells microns	5 88.8	cells microns
	Coal ashes	10.7	7.3	186.5	112.5	14 207.2	cells microns	5 74	cells microns
	Ammonium sulphate	10.3	7.7	186.5	125.8	13 266.4	cells microns	6 88.8	cells microns
	Control	11.2	7.9	192.4	136.2	15 251.6	cells Microns	6 88.8	cells microns
Green Mountain	Salt	11.6	..	210.8	....	15 255	cells microns	9 170	cells microns
	Sodium nitrate	11.8	..	224.4	....	16 306	cells microns	8 153	cells microns
	Slaked lime	10.5	..	187	....	15 255	cells microns	6 119	cells microns
	Fresh manure	No data, potatoes lost							
	Sulphur	14	..	251.6	....	18 306	cells microns	11 187	cells microns
	Acid phosphate	13	..	224.4	....	16 289	cells microns	10 170	cells microns
	Complete fertilizer	10.2	..	171.6	....	13 221	cells microns	8 136	cells microns
	Coal ashes	12.4	..	210.8	....	16 255	cells microns	10 170	cells microns
	Ammonium sulphate	11.2	..	192.1	....	15 238	cells microns	8 153	cells microns
	Control	12.5	..	210.8	....	17 272	cells microns	9 136	cells microns

TABLE XI—EFFECT OF CHEMICALS ON THICKNESS OF THE SKINS OF POTATO TUBERS—*continued*

Variety	Chemical or fertilizer used	Cell layers in thick portion	Cell layers in thin portion	Thickness, thick portion	Thickness, thin portion	Maximum thickness	Minimum thickness
				microns	microns		
Early Rose	Salt	12	238	....	....	16 cells 306 microns	10 cells 187 microns
	Sodium nitrate	11.3	207.4	....	....	15 cells 255 microns	9 cells 170 microns
	Slaked lime	11.6	215.9	....	....	15 cells 255 microns	9 cells 170 microns
	Fresh manure	11.2	210.8	....	....	14 cells 255 microns	9 cells 170 microns
	Sulphur	11.4	209.1	....	....	16 cells 255 microns	8 cells 153 microns
	Acid phosphate	11.1	192.8	....	....	14 cells 255 microns	8 cells 170 microns
	Complete fertilizer	10	183.6	....	....	13 cells 221 microns	7 cells 136 microns
	Coal ashes	10.8	203.2	....	....	15 cells 255 microns	8 cells 153 microns
	Ammonium sulphate	10.9	205.7	....	....	14 cells 255 microns	9 cells 170 microns
	Control	11.4	207.4	....	....	15 cells 272 microns	9 cells 153 microns
Scab Proof	Salt	19.4	9.4	307.7	147.9	23 cells 391 microns	7 cells 102 microns
	Sodium nitrate	17	8.8	272	139.4	22 cells 391 microns	7 cells 85 microns
	Slaked lime	15.7	9.2	232.9	127.5	20 cells 289 microns	7 cells 85 microns
	Fresh manure	16.5	8.7	260.1	141.1	20 cells 306 microns	7 cells 85 microns
	Sulphur	19	9.6	323	158.1	24 cells 425 microns	8 cells 119 microns
	Acid phosphate	16.7	8	275.4	128.2	20 cells 340 microns	6 cells 85 microns
	Complete fertilizer	17.3	8.5	277.1	133.8	21 cells 340 microns	6 cells 102 microns
	Coal ashes	17.5	8.2	280.5	136.6	21 cells 340 microns	6 cells 102 microns
	Ammonium sulphate	16.4	8	268.6	130.9	20 cells 340 microns	6 cells 85 microns
	Control	17	8.5	283.9	147.9	20 cells 374 microns	7 cells 102 microns

TABLE XI—EFFECT OF CHEMICALS ON THICKNESS OF THE SKINS OF POTATO TUBERS—*concluded*

Variety	Chemical or fertilizer used	Cell layers in thick portion	Cell layers in thin portion	Thickness, thick portion	Thickness, thin portion	Maximum thickness	Minimum thickness
				microns	microns		
Bovee (smooth potato)	Salt	10.5	229.46	8.3	172.48	....	....
	Sodium nitrate	none	none	7.1	152.46	....	....
	Slaked lime	none	none	10.2	229.46	....	....
	Fresh manure	10.5	227.44	8.1	160.16	....	....
	Sulphur	none	none	9.4	184.8	....	....
	Acid phosphate	none	none	7.3	160.16	....	....
	Complete fertilizer	11.9	226.38	7.7	155.54	....	....
	Coal ashes	10.3	212.52	7.6	158.62	....	....
	Ammonium sulphate	none	none	7.5	146.3	....	....
	Control	none	none	8.2	197.12	....	....
Russetted potato	Sodium nitrate	11.7	235.62	8.2	160.1	....	....
	Sulphur	11.5	264.88	9.0	164.8	....	....
	Ammonium sulphate	11.3	229.46	7.3	150.9	....	....

The results are not at all conclusive. An attempt was made with the Green Mountain tubers to arrive at an average of the thick and thin portions in the sections and to sum these up in one set of figures. No decided difference could be seen as a result of the treatment, expressed either as numbers of cell-layers or as thickness in microns. The maximum and minimum thicknesses also show only small differences, although it is true that a slightly thicker skin was observed on areas on which sulphur was spread and a somewhat thinner skin on those where lime was used.

Bovee is not at all consistent, either as to the cell layers or the thickness of the skin. The use of salt, sodium nitrate, lime and of fresh manure was followed by thinning of the skin in Dibble's Russet.

but sulphur and ammonium sulphate applications were followed by a thinner skin on the thin portions and in only a slightly thicker skin on the thicker portions from the sulphur.

Neither Early Rose nor Scab Proof manifested skin differences following these treatments, although in the latter instance when sulphur was used the skin was slightly thicker than the average, both in cell layers and in microns.

Several reasons may be advanced as to the inconclusiveness of these results.

(1) The chemicals may have leached from the light sandy soil thus minimizing their effect.

(2) The unusual season may have induced the formation of skins of relatively similar thicknesses regardless of the divergencies in chemical applications.

(3) The long winter storage of the tubers may have given the cork cambium a chance to continue growth, thus equalizing any differences in cork thickness which may have existed at harvest.

The 32 results were so inconclusive that the trial was repeated in 1917 on another piece of land, a sandy loam, somewhat different than that heretofore used. The amounts of fertilizer used were the same as in the previous year. The plants died prematurely from a combination of mosaic and tip burn, but formed enough tubers for the present studies. Many of the tubers, even when smooth, showed an abnormal browning under the cork layers, the cause of this trouble not being apparent. Circumstances made it impossible to cut the sections immediately after harvest and, consequently, the tubers were stored in soil in a greenhouse cellar for about six months. The soil and tubers were dampened and apparently no change took place in the superficial appearance of the skin.

TABLE XII—EFFECT OF CHEMICALS ON THICKNESS OF SKIN OF POTATO TUBERS

		Clean White Tubers				Russetted Tubers			
Variety	Chemicals or fertilizer used	Cell layers in thick portion	Cell layers in thin portion	Thickness in thick portion	Thickness in thin portion	Cell layer in thick portion	Cell layer in thin portion	Thickness in thick portion	Thickness in thin portion
				microns	microns			microns	microns
Dibble's Russet	Fresh manure	11.33	8.19	153	116.5	23.4	...	230	...
	Acid phosphate	13.29	7.37	198.4	110	17	...	264	...
	Lime	9	7	115	84.4	...	...	....	...
	Salt								
	(Large tubers)	11.08	7.9	157.5	113	...	...	....	...
	(Small tubers)	10.5	7.3	160	103.7	...	...	....	...
	Control	10.9	6.76	137	100	14.4	6.85	167	78
	Control (Smooth part of potato)	12.5	6.72	145	100	...	...	....	...
	Sulphur	11	8.14	188	121	10.6	6.22	138	89.2
	Sulphur (Potato browned)	13.8	none	200	none	...	...	....	...
	Ammonium sulphate	9	7	145	102	...	...	....	...
	(Large white)	....	...	....	....	...	...	....	...
	(Small white)	10.4	7.04	130	95	...	...	....	...
	(Russetted large)	....	...	....	....	11	7	155.9	94.2
Green Mountain	Acid phosphate								
	(Small tubers)	9.5	6.9	125	90.3	...	...	....	...
	(Large tubers)	10	6.8	130	92.5	...	...	....	...
	Salt	11.9	7.1	140	87.5	...	...	....	...
	Fresh manure	9.6	7.3	126	109	11.1	6.8	151	100
	Ammonium sulphate	9	7	150	94.4	13.3	6.5	152	92.5
	Sulphur	....	7.1	....	93.6	...	...	....	...
	Lime	9	6.5	126.6	92.2	9.9	6.5	128.8	96
Green Mountain (from-nursery plot)	Acid phosphate	12	7.85	170	129	10.7	7.45	145	54.5
	Sulphur	12.5	7.92	138.3	90	...	...	....	...
	Fresh manure	....	8.3	83	....	12.8	6.6	146	76.6
	Fresh manure (Potato browned)	....	...	....	....	...	13.1*	....	195.5
	Ammonium sulphate	16.4	6.5	214	75	...	...	....	...

*The 13.1 cell layers were composed of 5.1 layers of cork and 8 layers of tissue, which was apparently abnormal and gave the brown appearance to the surface. The total thickness, 195.5 microns was made up of 105 microns of cork and 90.5 microns of this other type of tissue.

Only two varieties—Dibble's Russet and Green Mountain—were used. Various combinations were tried in the collection of the data in the hope of ascertaining whether any changes occurred in the skins following the several soil treatments. Minor fluctuations in the cell layers and in the thickness in microns are to be observed but nothing that seems to indicate that the chemicals altered the skin, except that when sulphur was used both the number of the cell layers and the thickness of the skin seemed to be increased. The cell layers resulting from the treatment with fresh manure were almost as numerous as those from the sulphur, and yet manure helps the scab organism whereas sulphur seems to retard its growth.

The Green Mountain potatoes taken from another plot at some distance from the first set seemed to exhibit a somewhat thicker skin. The soil of this plot (known as the nursery plot) was even sandier than that on which the other Green Mountains and Dibble's Russets grew. The results received when sulphur, fresh manure and ammonium sulphate were applied were the opposite of those to be expected in view of the effect produced by these chemicals on the amount of scab; that is to say, these treatments seemed to make the skin thinner.

These general results were so inconclusive that trials were made by plate cultures on the effect on the bacteria of the Actinomyces chromogenus group. No conclusions could be drawn from the results obtained. The soil samples were taken in the furrows where the chemicals had been distributed, the dilutions were plated out on nutrient agar and counts made of the organisms producing a distinctly brown color around the colonies. Güssow (8) and Dreschler (5) contend that only a portion of the A. chromogenus group (known by them as A. scabies) is parasitic. Even if this be true, probably it would not affect these counts, since all of this group would be likely to be influenced in about the same way by the chemicals employed in the soil. The counts showed no decided differences follownig these various treatments. It is the belief of the writer, however, that such chemicals as sulphur affect the scab organism rather than the thickness of the tuber skin. The effect on the organisms may not result in a decided decrease in their numbers, but their vigor and pathogenicity may be weakened.

GENERAL CONCLUSIONS

1. The thickness of the skin determines the resistance of the tubers to scab. Color seems to play no role in this resistance. All russet varieties seem at least moderately resistant.

2. Close textured lenticels, partly buried under the skin surface and filled with small cells, are also associated with the russet type of potatoes.

3. The application of certain fertilizers and chemicals to the soil affects to some extent the amount of scab, sulphur and ammonium sulphate tending to decrease and lime and manure to increase it.

4. The skin structure seems to be but slightly affected by these applications, at least on sandy soil; hence it seems probable that any changes which they may bring about in the prevalence of scab is due to their effect on the numbers or the pathogenicity of the organisms rather than on the tuber itself.

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